Dewberry®

PROJECT REPORT

For the

USGS PAgis V13 LiDAR Processing

USGS Contract:

G10PC00013

Task Order Number:

G11PD01289

Prepared for:
USGS

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Report Date: April 6, 2012

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1 Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from recently acquired high-accuracy Light Detection and Ranging (LiDAR) data set of 576 square miles for the USGS Pulaski County project area.

The LiDAR data were processed to a bare-earth digital elevation model (DEM). Detailed breaklines, a terrain dataset, 3D contours, and bare-earth DEMs were produced for the project area. Data was formatted according to tiles with each tile covering an area of 10,000 ft by 10,000 ft. A total of 199 tiles were produced for the project encompassing an area of approximately 576 sq. miles.

The Project Team

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for breakline production, 3D contours, Digital Elevation Model (DEM), quality assurance, and the final LAS classification of the data. In contrast to other LiDAR tasks, there is no LiDAR acquisition associated with this task.

Checkpoints were established by FEMA during the LiDAR collection process. Because the data was flown together and calibrated to a single geodetic network, Dewberry checked the relative accuracy of the newly processed data against the FEMA data. Independent testing of the vertical accuracy of the LiDAR-derived surface model was also done by Dewberry using the surveyed checkpoints. Note that a separate Survey Report was created for this portion of the project.

Fugro EarthData completed LiDAR data acquisition, data calibration, and initial LAS classification for the project area.

Survey Area

The project area addressed by this report falls within the Arkansas counties of Faulkner, Perry, Lonoke, Saline, and Pulaski.

Date of Survey

The LiDAR aerial acquisition was conducted by Fugro EarthData from December 27, 2010 thru January 27, 2011.

Datum Reference

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 (NAD 83)
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: Arkansas State Plane Coordinate System, North Zone
Units: Horizontal units are in US Survey Feet, Vertical units are in Feet.
Geiod Model: Geoid09 (Geoid 09 was used to convert ellipsoid heights to orthometric heights).

LiDAR Vertical Accuracy

The USGS PAgis LiDAR project was flown as part of a larger FEMA LiDAR project. The vertical accuracy of the FEMA project was tested by RAMPP and the $RMSE_z$ for the 21 open terrain checkpoints equaled **0.11 ft** compared with the 0.41 ft specification, the consolidated $RMSE_z$ for all 83 checkpoints (urban, forested, high grass, low grass and bare earth) equaled **0.17 ft** compared with the 0.41 ft specification; and the FVA computed using $RMSE_z$ x 1.9600 was equal to **0.22 ft**, compared with the 0.8 ft specification.

The vertical accuracy of the newly processed data was tested by Dewberry and the $RMSE_z$ for the 21 open terrain checkpoints equaled **0.13 ft** compared with the 0.41 ft specification, the consolidated $RMSE_z$ for all 83 checkpoints (urban, forested, high grass, low grass and bare earth) equaled **0.15 ft** compared with the 0.41 ft specification; and the FVA computed using $RMSE_z$ x 1.9600 was equal to **0.26 ft**, compared with the 0.8 ft specification.

The tested CVA computed using the 95th percentile for the FEMA project was determined by RAMPP to equal **0.33 ft,** compared with the 1.19 ft specification.

The tested CVA computed using the 95th percentile for the newly processed data was determined by Dewberry to equal **0.28 ft,** compared with the 1.19 ft specification.

Project Deliverables

The deliverables for the project are listed below.

1. Raw Point Cloud Data (Swaths)
2. Classified Point Cloud Data (Tiled)
3. Bare Earth Surface (Raster DEM – ESRI Arc Grid Format)
4. Intensity Images (GeoTIFF format)
5. Hydro-flattened Terrain Dataset
6. 3D Contours with a two foot interval (File GDB)
7. Metadata
8. Project Report (Acquisition, Processing, QC)
9. Project Extents Derived from LiDAR Deliverable
10. Control & Accuracy Checkpoint Report & Points
11. Breakline Data (File GDB)

2 Project Tiling Footprint

One hundred and ninety-nine (199) tiles were delivered for the project. Each tile's extent is 10,000 feet by 10,000 feet.

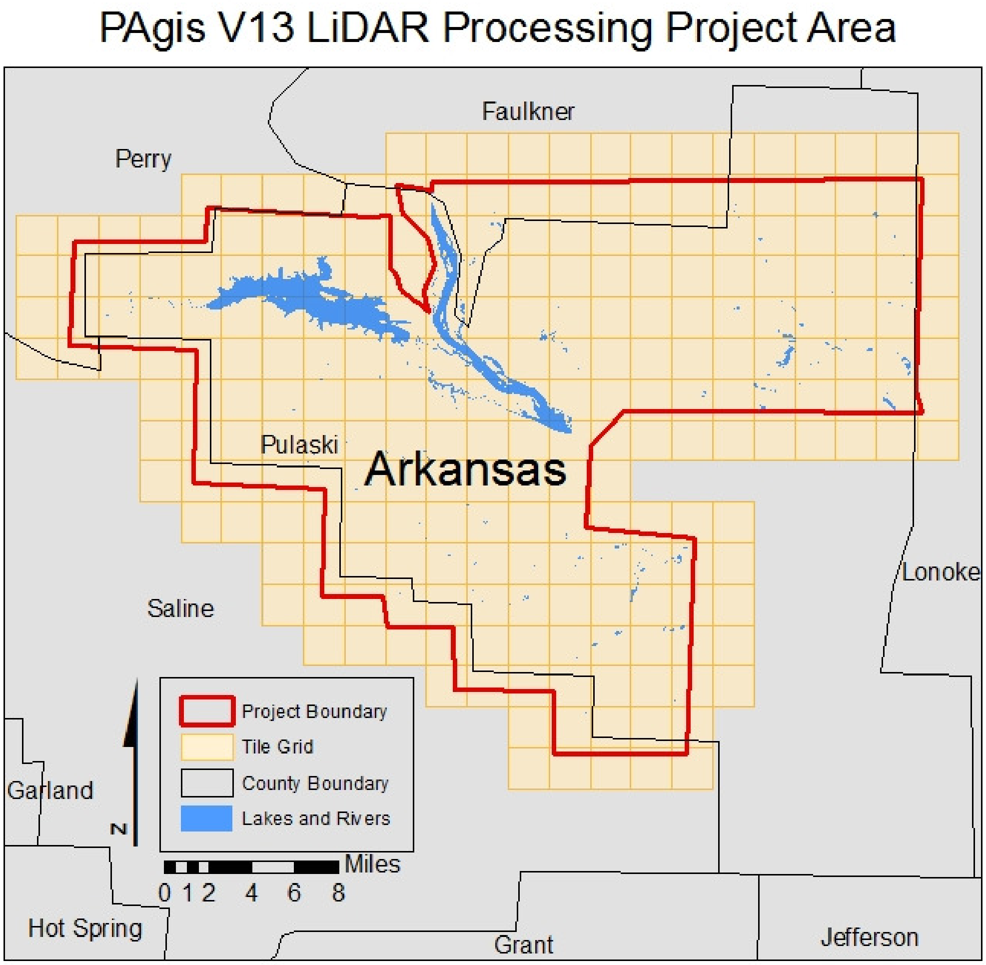
PAgis V13 LiDAR Processing Project Area

Figure 1: Project Map

2.1 List of delivered tiles (199):

15WU0818
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3 LiDAR Acquisition Report

3.1 *ACQUISITION*

Topographic data in the format of LAS was acquired by Fugro EarthData in December 2010 and January 2011. The study area consists of one Area of Interest (AOI) in Pulaski County and covers the area of approximately 564 square miles; the boresighted unclassified LAS data for the AOI was delivered in full swath LAS format. The data collection included a 100 meter perimeter buffer. The full acquisition AOI (564 square miles) was processed to Level 1: raw boresighted flight line swaths in LAS format. A 165 square mile subsection of the AOI was process to Level 2: a fully calibrated, classified point cloud in LAS format.

Figure 1 depicts the project area for the AOI that is included in this delivery. The purple flight lines outline the extent of the collected data, and the red line depicts the area processed to level 2.

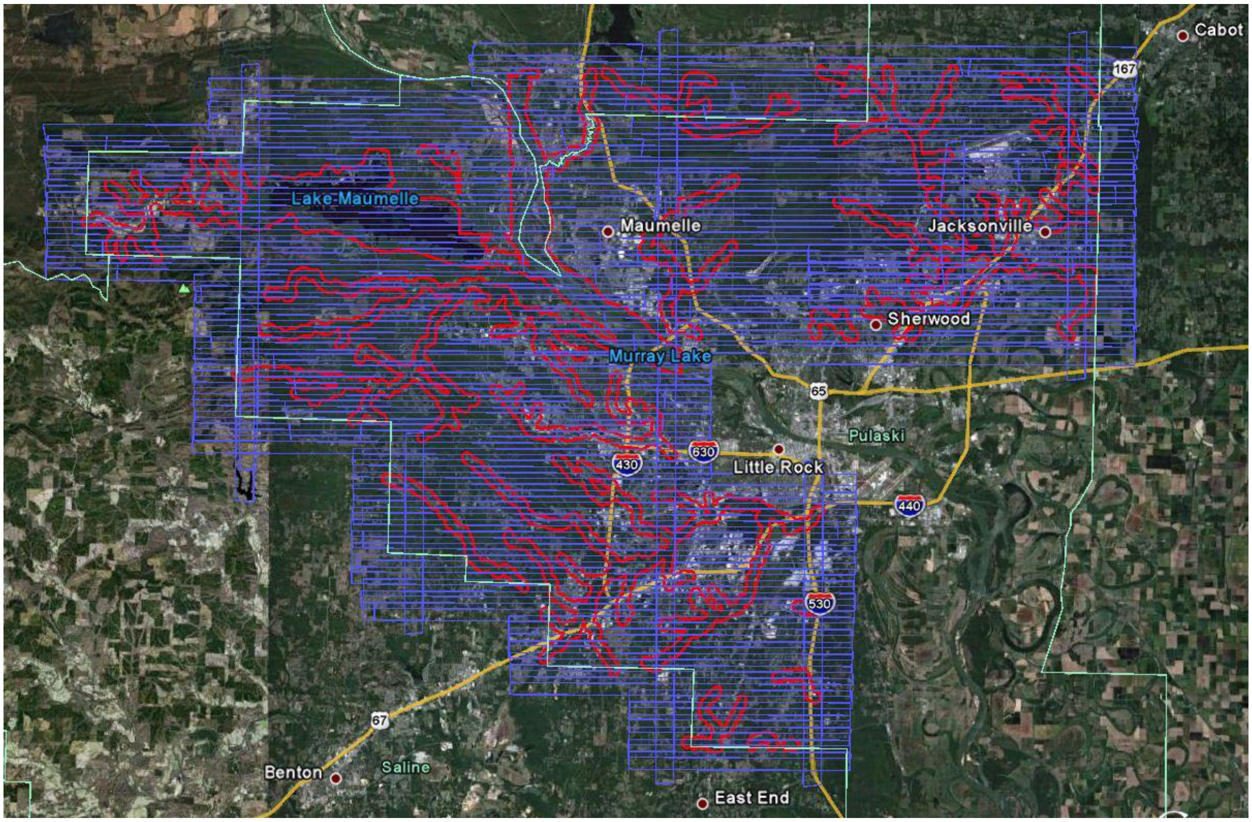


Figure 2- Pulaski AOI data coverage

3.2 *PROCESSING*

Processing of the LiDAR data begins with refinement of the initial boresight alignment parameter in the ALS Processor configuration file (.reg) delivered with the raw data. For projects that have more than one lift, the boresight for each lift has to be completed individually because it may differ slightly from lift to lift. Lift boresighting is accomplished using the tri-directional calibration flight lines over the project area. One calibration flight line is flown bi-directionally overlapping a project flight line within the lift. This bi-directional calibration will also be used as a parallel flight line with the adjacent flight line. There is a cross flight line collected perpendicular to both. All three lines along with the parallel project flight line are examined to ensure that they agree, within expected system tolerances, in the overlapping areas. The two bi-directional flight lines are used to diagnose Roll and Pitch. The two parallel flight lines are used to diagnose and correct Heading error. The two perpendicularly overlapping flight lines are used to examine Variable Scan Angle error. To begin lift boresight, the raw LiDAR data of the calibration flight lines will be processed with the initial boresight parameters determined from the LiDAR Sensor Calibration. Once the boresighting is done for the calibration flight lines, the adjusted settings will be applied to the complete lift and checked for consistency. For a well maintained LiDAR system, functioning correctly under normal operating conditions, actual boresight angles can be considered constant throughout a single mission. Therefore, once the boresight angles have been adjusted based on the calibration flight lines, the same corrections can be applied to the entire lift. Under optimal circumstances, the boresight parameters determined for the calibration flight lines should be the same for all flight lines in the lift, but residual errors can occur. To correct for this, all of the overlaps between flight lines (side lap) and intersections of the project cross flight lines should be examined for internal consistency. If the results of the boresights start showing drift in the middle of the lift or the misalignment between flight lines starts exceeding project accuracy specifications, boresight parameters need to be adjusted to correct these errors. Once boresight adjustments are completed for each individual lift, the technician checks and corrects the vertical misalignment of all the flight lines and also the matching between data and ground truth. This process includes calculating the zbias value for each flight line so that all flight lines are vertically aligned and the entire data set match to the ground control points within the project specified accuracy range. The technician will run a final vertical accuracy check after the z correction. The result will be analyzed against the project specified accuracy to verify it meets the requirement.

3.3 DATA EVALUATION

RAMPP evaluated the LAS data and provided final LiDAR QA report for Pulaski County, AR confirming that the data meets the project specification.

4 GPS Control and Survey Report

4.1 Summary

ESP Associates, P.A. preformed a total of 83 LiDAR checkpoint surveys within Pulaski County, AR between January 4 and January 16, 2011. The total number of checkpoints is divided into the following categories: 21 Category A (Bare Earth/ Low Grass), 22 Category B (High Grass/Weeds/Crops), 20 Category D (Fully Forested) and 20 Category E (Urban). Category A checkpoints were spread over a 587 square mile processing area. All LiDAR checkpoint surveys were performed in accordance with RAMPP’s Guidelines for Performing Surveying of LiDAR checkpoints.

4.2 GPS Control & Survey Procedures

ESP used fast-static GPS observation methods to survey the Category A, B and E checkpoints and the control pairs used to conventionally survey the Category D checkpoints. ESP established three temporary GPS base stations (Base01JC, Base02JC, and Base03JC) within the project area and also used NGS monument LR 2 (AE2992) as a base point. The elevations for Base 01, 02 and 03 were derived from conventional leveling from NGS benchmarks P 290 (EJ1672), E 321 (DK2859) and WAX (EJ0430) respectively, while there horizontal positions were established via NGS OPUS solutions. Each new LiDAR QC checkpoint, with the exception of Category D points, were established via fast-static GPS observations using one of the four base stations (Base01JC, Base02JC, Base03JC and LR 2) in conjunctions with the Little Rock CORS ARP.

The CORS used in the OPUS solutions for determining the horizontal positions for the three new base stations were ROCKYHILLAR_2008 CORS ARP (DL7767), LITTLE ROCK CORS SRP (DH7107), BATESVILLE CORS ARP (DH8992) and MONTICELLO COOP CORS ARP (DF3567). ESP used the same LiDAR QC observation methods to check into two NGS monuments (K 320 and X 71) in order to ensure that other local benchmark elevations would agree with our fast-static GPS observation methods. The differences between the GPS-observed elevations area shown below:

NGS Monument	PID	V Delta	H Delta
K 320	DK2839	0.03’	N/A
X 71	EJ0245	0.11’	N/A

4.3 Survey Data

The final coordinates and elevations of the LiDAR QC checkpoints are shown on pages 13-15 of the survey TSDN. The data is sorted by QC checkpoint name, northing, easting, elevation, method of observation/collection and units. The point names are designated by the following scheme “PC_B_01” whereas the first two letters represent the county (Pulaski); the second letter represents the point ID number falling between 01 and 83.

The horizontal and vertical datum of these surveyed LiDAR QC checkpoints are the NAD83/CORS96 Epoch 2002 and NAVD 88 respectively. The coordinates referred to in this report are based on the Arkansas South Central Zone (0302) State Plane Coordinate System. These LiDAR QC checkpoints meet or exceed a 5 cm (0.016 feet) horizontal and vertical accuracy, with a 95% confidence level, relative to the primary control mentioned above (CORS and local benchmarks). Geoid 09 was used to establish the GPS-derived orthometric heights. All project coordinates and elevations are listed in US Survey Feet unless otherwise noted. This LiDAR Quality Control checkpoint project was performed under the supervision of a licensed Arkansas Professional Land Surveyor.

Please contact Daniel B. Hill, PLS (Senior Survey Project Manager) at 803-802-2440 if you have any questions regarding the contents of this survey report.

Kenneth E. Hauck, License No. 1325

NO. 1325

KENNETH EDWIN HAUCK

3/1/11

Date

5 LiDAR Processing & Qualitative Assessment

5.1 Data Classification and Editing

LiDAR mass points were produced to LAS 1.2 specifications, including the following LAS classification codes:

- Class 1 = Unclassified, and used for all other features that do not fit into the Classes 2, 7, 9, or 10, including vegetation, buildings, etc.
- Class 2 = Ground, includes accurate LiDAR points in overlapping flight lines
- Class 7 = Noise, low and high points
- Class 9 = Water, points located within collected breaklines
- Class 10 = Ignored Ground due to breakline proximity.
- Class 11 = Withheld, points that exceed the maximum allowable scan angle.

The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing project defined tile boundary index encompassing the entire project areas. The data initially received for flightline LDR101228_012823_1_s0 was unreadable resulting in a lack of coverage of the entire project area. Once Fugro EarthData corrected the data and redelivered, the acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and divided into file size optimized tiles. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine removes any obvious outliers from the dataset following which the ground layer is extracted from the point cloud. Points with higher scan angles have the potential to introduce issues in the surface model. Therefore, points with scan angles greater than plus or minus 19 degrees were classified to class 11, withheld prior to running the ground routine. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Once the data has been auto-classified the LAS format 1.0 format points are converted to LAS 1.2 Point Data Record Format 1 and converted to the required ASPRS classification scheme (1=Unclassified,2=ground,7=noise/flyers) from Terrapoint Proprietary classification scheme.

The following fields within the LAS files are populated to the following precision: GPS Time (0.000001 second precision), Easting (0.01 foot precision), Northing (0.01 foot precision), Elevation (0.01 foot precision), Intensity (integer value - 12 bit dynamic range), Number of Returns (integer - range of 1-4), Return number (integer range of 1-4), Scan Direction Flag (integer - range 0-1), Classification (integer), Scan Angle Rank (integer), Edge of flight line (integer, range 0-1), User bit field (integer - flight line information encoded). The LAS file also contains a Variable length record in the file header.

Dewberry utilizes a variety of software suites for data processing. The LAS dataset was received and imported into GeoCue task management software and retiled into 5,000 ft by 5,000 ft tiles for processing in Terrascan. Each tile was imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, bridges and ridges that were present following the initial processing conducted by Terrapoint. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. The final classification routine applied to the dataset selects ground points within a specified distance of the water breaklines and classifies them as class 10, ignored ground due to breakline proximity. Once the dataset was finalized, the LAS was imported into GeoCue task management software and retiled into 10,000 ft by 10,000 ft tiles.

After all processing and classification has been completed, GeoCue software is used to update the LAS version, projection information, creation day, and creation year of every LiDAR file.

5.2 Qualitative Assessment

Dewberry qualitative assessment utilizes a combination of statistical analysis and interpretative methodology to assess the quality of the data for a bare-earth digital elevation model (DEM). This process looks for anomalies in the data and also identifies areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model.

Within this review of the LiDAR data, two fundamental questions were addressed:

- Did the LiDAR system perform to specifications?
- Did the vegetation removal process yield desirable results for the intended bare-earth terrain product?

Mapping standards today address the quality of data by quantitative methods. If the data are tested and found to be within the desired accuracy standard, then the data set is typically accepted. Now with the proliferation of LiDAR, new issues arise due to the vast amount of data. Unlike photogrammetrically-derived DEMs where point spacing can be eight meters or more, LiDAR nominal point spacing for this project is 1 point per 1 square meter. The end result is that millions of elevation points are measured to a level of accuracy previously unseen for traditional elevation mapping technologies and vegetated areas are measured that would be nearly impossible to survey by other means. The downside is that with millions of points, the dataset is statistically bound to have some errors both in the measurement process and in the artifact removal process.

As previously stated, the quantitative analysis addresses the quality of the data based on absolute accuracy. This accuracy is directly tied to the comparison of the discreet measurement of the survey checkpoints and that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement. Once the absolute and relative accuracy has been ascertained, the next stage is to address the cleanliness of the data for a bare-earth DEM.

By using survey checkpoints to compare the data, the absolute accuracy is verified, but this also allows us to understand if the artifact removal process was performed correctly. To reiterate the quantitative approach, if the LiDAR sensor operated correctly over open terrain areas, then it most likely operated correctly over the vegetated areas. This does not mean that the entire bare-earth was measured; only that the elevations surveyed are most likely accurate (including elevations of treetops, rooftops, etc.). In the event that the LiDAR pulse filtered through the vegetation and was able to measure the true surface (as well as measurements on the surrounding vegetation) then the level of accuracy of the vegetation removal process can be tested as a by-product.

To fully address the data for overall accuracy and quality, the level of cleanliness (or removal of above-ground artifacts) is paramount. Since there are currently no effective automated testing procedures to measure cleanliness, Dewberry employs a combination of statistical and visualization processes. This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models. By creating multiple images and using overlay techniques, not only can potential errors be found, but Dewberry can also find where the data meets and exceeds expectations. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

5.3 Analysis

Dewberry utilizes GeoCue software as the primary geospatial process management system. GeoCue is a three tier, multi-user architecture that uses .NET technology from Microsoft. .NET technology provides the real-time notification system that updates users with real-time project status, regardless of who makes changes to project entities. GeoCue uses database technology for sorting project metadata. Dewberry uses Microsoft SQL Server as the database of choice. Specific analysis is conducted in Terrascan and QT Modeler environments.

Following the completion of LiDAR point classification, the Dewberry qualitative assessment process flow for the USGS PAgis V13 LiDAR project incorporated the following reviews:

1. *Format:* The LAS files are verified to meet project specifications. The LAS files for the USGS PAgis V13 LiDAR project conform to the specifications outlined below.

   - Format, Echos, Intensity

    - LAS format 1.2, point data record format 1
    - Point data record format 1
    - Multiple returns (echos) per pulse
    - Intensity values populated for each point
- ASPRS classification scheme
    - Class 1 – Unclassified
    - Class 2 – Bare-earth ground
    - Class 7 – Noise
    - Class 9 – Water
    - Class 10 – Ignored Ground due to breakline proximity
    - Class 11- Withheld, points that exceed the maximum allowable scan angle
- Projection
    - Datum – North American Datum 1983
    - Projected Coordinate System – State Plane Arkansas North
    - Units – U.S. Survey Feet
    - Vertical Datum – North American Vertical Datum 1988, Geoid 09
    - Vertical Units - Feet
- LAS header information:
    - Class (Integer)
    - GPS Week Time (0.0001 seconds)
    - Easting (0.01 foot)
    - Northing (0.01 foot)
    - Elevation (0.01 foot)
    - Echo Number (Integer 1 to 4)
    - Echo (Integer 1 to 4)
    - Intensity (8 bit integer)
    - Flight Line (Integer)
    - Scan Angle (Integer degree)

2. *Data density, data voids:* The LAS files are used to produce Digital Elevation Models using the commercial software package “QT Modeler” which creates a 3-dimensional data model derived from Class 2 (ground points) in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas. For the USGS PAgis V13 LiDAR project it is stipulated that the minimum post spacing in un-obscured areas should be 1 point per 1 square meter.

    a. Two data voids exist within the USGS PAgis V13 LiDAR project area. One occurs in delivered tile 15WU1622 and is approximately 0.08 square miles. The second occurs in delivered tile 15WU2116 and is approximately 0.13 square miles. Dewberry would normally ensure that tiles within the project boundary contain data to the full extent of each tile and gaps in the data at the project boundary would be unacceptable but, as noted in the Task Order, Dewberry was not tasked with the LiDAR acquisition for the project area.

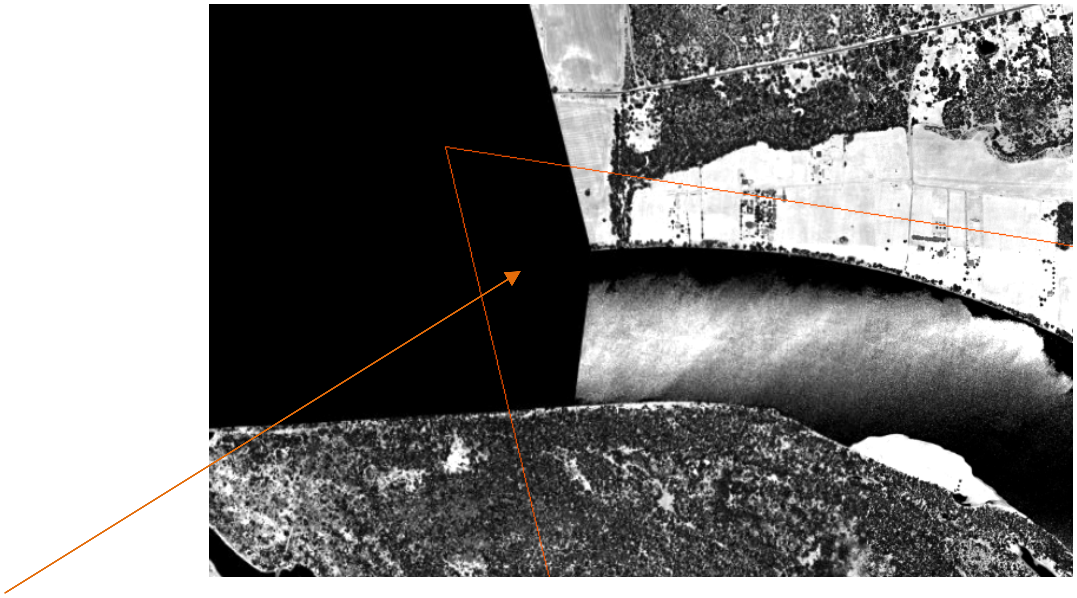


Figure 3 – Intensity for tile 15WU1622 showing the ~0.08 square mile data void within the project boundary shown in orange.

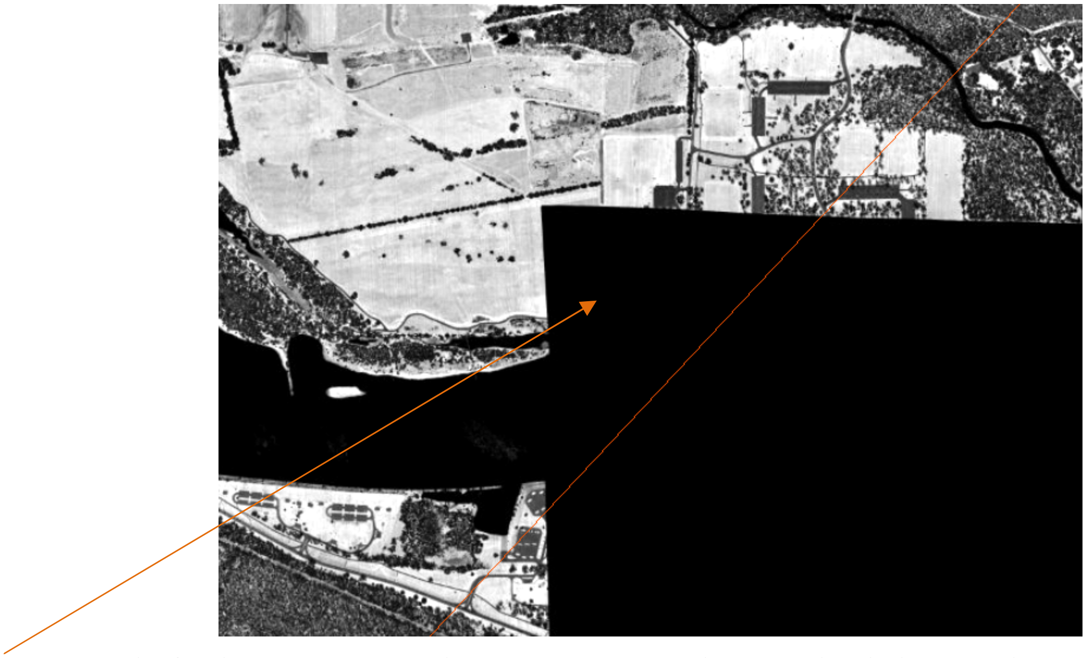


Figure 4 – Intensity for tile 15WU2116 showing the ~0.13 square mile data void within the project boundary shown in orange.

b. Acceptable voids (areas with no LiDAR returns in the LAS files) that are present in the majority of LiDAR projects include voids caused by bodies of water. These are considered to be acceptable voids.

3. *Bare earth quality:* Dewberry reviewed the cleanliness of the bare earth to ensure the ground has correct definition, meets the project requirements, there is correct classification of points, and there are less than 5% residual artifacts.

   a. *Building Removal:* Large buildings, unique construction, and buildings built on sloped terrain or built into the ground can make a noticeable impact on the bare earth DEM once they have been removed, often in the form of large void areas with obvious triangulation or interpolation across the area and general lack of detail in the ground where the structure stood. Dewberry analysts verified that structures have been removed from the ground, that areas along slopes missing definition are due to structural or vegetation removal and not aggressive classification, and that holes or removal of ground is accurate.

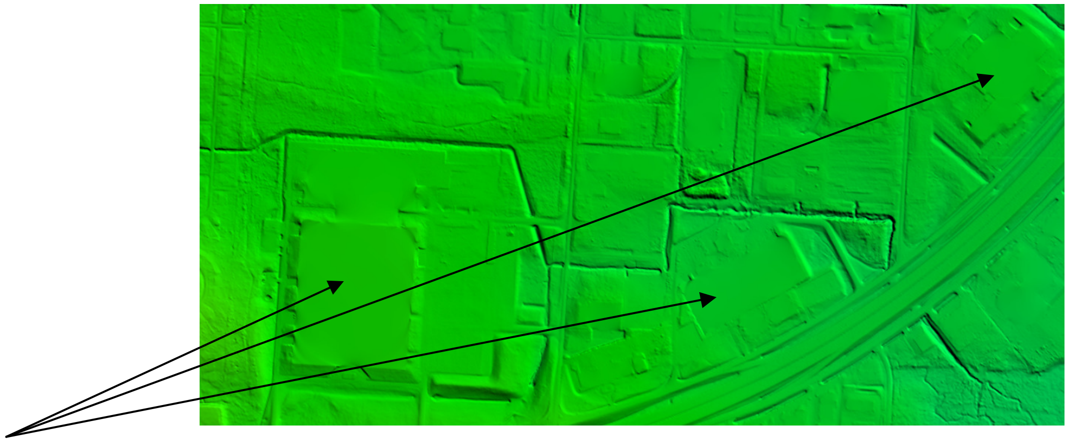


Figure 5 – DEM surface for tile 15WU2112. The figure shows area where large buildings have been removed from the ground correctly.

   b. *Flight Line Ridges:* During Dewberry's initial review of the data, Dewberry identified ridges in the existing ground classification. On average, these ridges were 0.25 feet in elevation, but varied in elevations with the maximum elevation identified at 0.80 feet. All ridges were located in areas of flight line overlap where one flight line is slightly offset from the overlapping flight lines. The offset usually occurs toward the edge of a flight line. Due to inherent LiDAR sensor properties, the edges of flight lines are slightly less accurate than nadir, or directly beneath the LiDAR sensor. The ridges were present in the ground surface, even after re-classifying points with high scan angles out of the ground classification. Changing the scan angle threshold only moved the boundary of the issue and did not correct the ridge issue. In order to correct this issue, Dewberry applied an additional ground algorithm that removes some of the overlapping points so that at one XY coordinate there are fewer ground points with a smaller range in elevations. This algorithm reduces the noise in the ground classification by choosing most of the ground points from one flight line rather than using both overlapping flight lines. While this algorithm does thin the final ground classification, the thinning is minor. The majority of all ridges have been removed. A limited number of flight line ridges are still visible in the final DEMs but they are within project specifications. The figures below show the ridges and examples of the same area after Dewberry's smoothing algorithm has been applied as well as a ridge that is within tolerance.

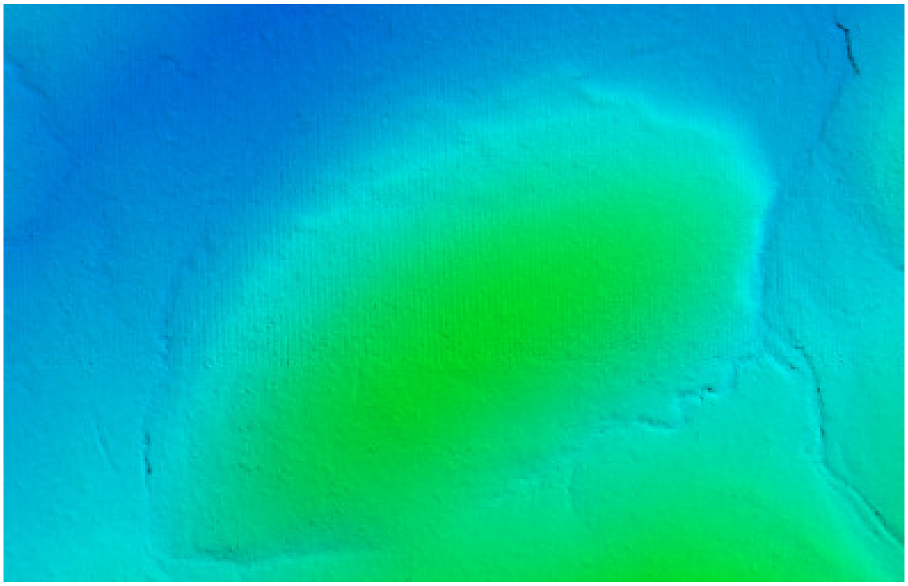


Figure 6 –Tile 15WU2120 DEM. Before Dewberry's smoothing algorithm, ridges of approximately 0.77 feet are present in the existing ground surface.

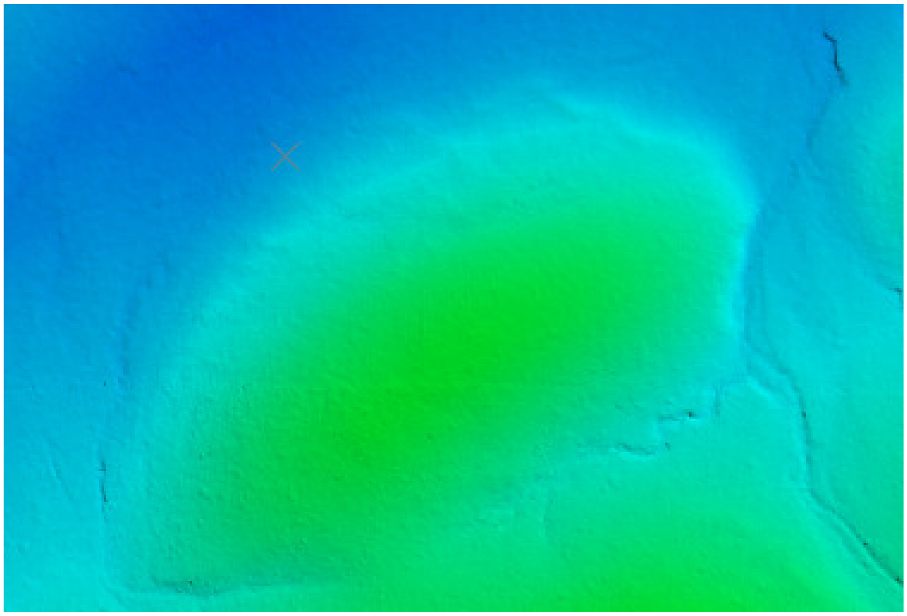
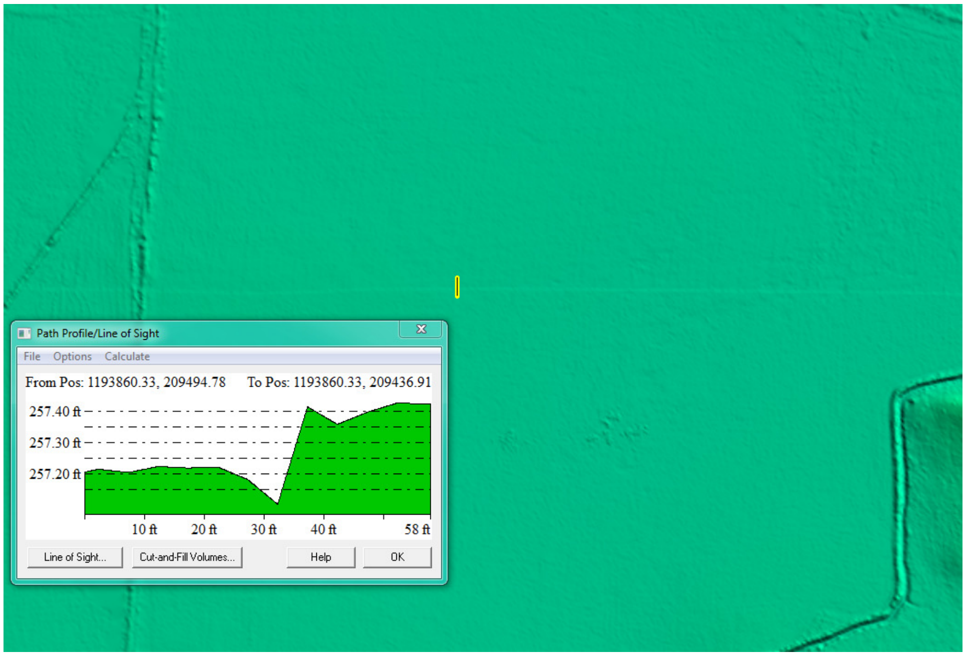


Figure 7 – Tile 15WU2120 DEM .The ridges are not present in the final ground surface after Dewberry's smoothing algorithm.



From Pos: 1193860.33, 209494.78 To Pos: 1193860.33, 209436.91

Figure 8-Tile 15WU1920 DEM. The flight line ridge is less than 0.3 ft. Overall, the PAgis V13 data meets the project specifications for 0.41 ft RMSE relative accuracy.

c. *In Ground Structures:* There are in ground structures located in portions of the PAgis project area. Some of these features can look out of place in areas of little elevation change. However, viewing the LiDAR data in profile shows that they are correctly left in the ground and are not artifacts that should be removed.

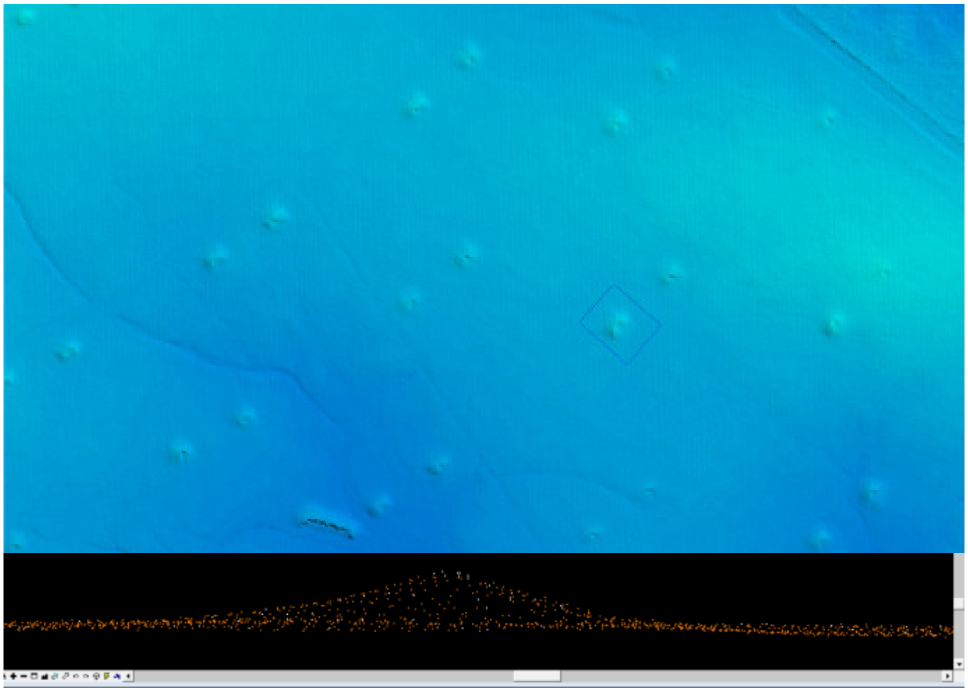


Figure 9 – Tile 15WU2220. The top view shows an elevation model of the area and the location of the profile. The bottom view shows a profile of the in ground structure where the unclassified points are white and the ground points are orange. The profile shows that the feature has correctly been left as ground.

5.4 Conclusion

The dataset conforms to project specifications for format and header values. The spatial projection information and classification of points is correct. Buildings, vegetation and other artifacts have been removed from the bare earth ground. A limited number of flight line ridges are present in the dataset, but these ridges are within project specifications.

6 Survey Vertical Accuracy Checkpoints

POINT ID	EASTING (FT)	NORTHING (FT)	ELEVATION (FT)
STATE PLANE ARKANSAS NORTH, U.S. SURVEY FEET			
PC_A_02	1184099.95	225143.29	293.58
PC_A_06	1212847.21	181115.06	318.86
PC_A_10	1198808.30	187405.13	265.00
PC_A_12	1171157.19	191987.98	270.18
PC_A_16	1088493.77	198065.28	370.24
PC_A_21	1136121.51	165179.19	410.95
PC_A_25	1171526.71	173441.09	289.93
PC_A_28	1203830.99	150083.45	313.29
PC_A_29	1200392.70	141468.42	333.25
PC_A_33	1196799.64	123978.28	290.05
PC_A_36	1203210.83	132655.52	255.65
PC_A_46	1178875.29	108592.84	326.60
PC_A_47	1187092.15	113557.63	305.49

PC_A_50	1213850.90	92197.18	292.99
PC_A_53	1253437.58	196411.37	285.25
PC_A_55	1244853.82	189697.39	409.33
PC_A_64	1242110.38	182222.81	423.92
PC_A_66	1285743.81	190536.60	284.82
PC_A_73	1160600.02	174967.04	364.40
PC_A_74	1167193.00	173981.47	318.24
PC_A_78	1182303.49	181923.56	260.16
PC_B_01	1179467.13	211926.46	275.41
PC_B_05	1204409.49	174011.74	274.97
PC_B_09	1180194.07	200039.83	267.34
PC_B_13	1159332.77	212667.70	289.58
PC_B_20	1158113.91	155945.48	457.50
PC_B_22	1119096.28	167867.71	552.80
PC_B_30	1188231.85	136400.49	353.62
PC_B_34	1199856.54	126263.94	279.63
PC_B_37	1212553.89	137876.28	249.39
PC_B_38	1221021.13	129754.64	259.69
PC_B_41	1208353.41	117545.44	286.70
PC_B_42	1195493.49	120387.92	303.78
PC_B_43	1192687.98	117743.77	310.58
PC_B_57	1243422.15	209744.41	321.14
PC_B_58	1265146.96	216314.10	337.62
PC_B_59	1275686.75	218236.36	308.63
PC_B_67	1285943.96	198955.31	258.70
PC_B_69	1261541.53	212910.39	297.09
PC_B_70	1255632.63	221058.24	277.49
PC_B_71	1174919.30	159263.75	580.95
PC_B_76	1179291.42	173868.86	255.78
PC_B_77	1186189.70	175558.23	261.20
PC_D_03	1190390.08	200834.45	299.16
PC_D_08	1208494.89	205418.68	295.54
PC_D_11	1163767.18	184315.19	259.03
PC_D_14	1115445.41	199434.15	306.98
PC_D_23	1143012.04	177013.45	357.03
PC_D_24	1150838.55	178778.20	333.98
PC_D_31	1168010.27	127795.46	381.33
PC_D_32	1171230.45	135691.10	464.04
PC_D_35	1203776.03	127600.45	272.32
PC_D_39	1213796.21	115741.21	265.32
PC_D_44	1186786.14	117470.95	287.66
PC_D_48	1207187.12	125728.04	287.73
PC_D_52	1255436.82	198272.58	249.31
PC_D_54	1251609.19	190860.87	279.21
PC_D_61	1260925.29	189441.34	241.57
PC_D_63	1261518.38	183193.07	259.87
PC_D_80	1260370.51	203838.70	365.90
PC_D_81	1268093.58	221220.71	296.81

PC_D_82	1285443.09	213473.05	263.53
PC_D_83	1274326.78	222331.53	273.23
PC_E_04	1191898.72	191280.68	289.07
PC_E_07	1208852.74	195910.74	281.76
PC_E_15	1106287.14	200303.32	313.13
PC_E_17	1147794.85	183469.79	317.50
PC_E_18	1191887.33	162265.27	459.30
PC_E_19	1178033.17	160197.80	604.98
PC_E_26	1198235.91	155357.71	399.53
PC_E_27	1202736.91	161688.34	555.29
PC_E_40	1216488.83	122028.98	263.64
PC_E_45	1182418.84	115875.40	306.56
PC_E_49	1218592.81	109876.77	334.12
PC_E_51	1215807.74	101220.92	410.46
PC_E_56	1240339.98	197459.03	285.90
PC_E_60	1281854.73	210675.28	271.59
PC_E_62	1257610.78	182174.25	257.18
PC_E_65	1273849.65	190777.37	241.39
PC_E_68	1274506.15	201167.24	316.03
PC_E_72	1170415.44	165678.40	643.58
PC_E_75	1180670.34	170160.32	315.48
PC_E_79	1189832.72	151841.90	499.35

Table 1- USGS PAgis V13 LiDAR surveyed accuracy checkpoints

7 LiDAR Vertical Accuracy Statistics & Analysis

7.1 Background

Dewberry tests and reviews project data both quantitatively (for accuracy) and qualitatively (for usability).

For qualitative assessment (i.e. vertical accuracy assessment), eighty-three (83) check points were surveyed for the project and are located within bare earth/low grass, high grass/weeds/crops, forested, and urban land cover categories. The checkpoints were surveyed for the project using RTK survey methods. A survey report was produced which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the “dispersed method” of placement.

7.2 Vertical Accuracy Test Procedures

FVA (Fundamental Vertical Accuracy) is determined with check points located only in land cover category (1), open terrain (bare earth/low grass), where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The FVA determines how well the calibrated LiDAR sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the USGS PAgis V13 LiDAR project, vertical accuracy must be 0.80 ft or less based on an RMSEz of 0.41 ft x 1.9600.

CVA (Consolidated Vertical Accuracy) is determined with all checkpoints in all land cover categories combined where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. CVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all land cover categories combined. The USGS PAgis V13 LiDAR Project CVA standard is 1.19 ft at the 95% confidence level. The CVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the CVA; these are always the largest outliers that may depart from a normal error distribution. Here, Accuracy_z differs from CVA because Accuracy_z assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas CVA assumes LiDAR errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in the table below.

Quantitative Criteria	Measure of Acceptability
Consolidated Vertical Accuracy (CVA) in all land cover categories combined = 95% confidence lever	1.19 ft (based on combined 95th percentile)
Fundamental Vertical Accuracy (FVA) in open terrain using RMSEz *1.9600	0.80 ft (based on RMSEz * 1.9600)

Table 2- Acceptance Criteria

7.3 Vertical Accuracy Testing Steps

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications. Figure 9 shows the location of the checkpoints.
2. Next, Dewberry interpolated the bare-earth LiDAR DEM to provide the z-value for each of the 83 checkpoints.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the LiDAR data and the ground truth survey checkpoints and computed CVA values.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

The figure below shows the location of the QA/QC checkpoints within the project area.

Checkpoint Locations

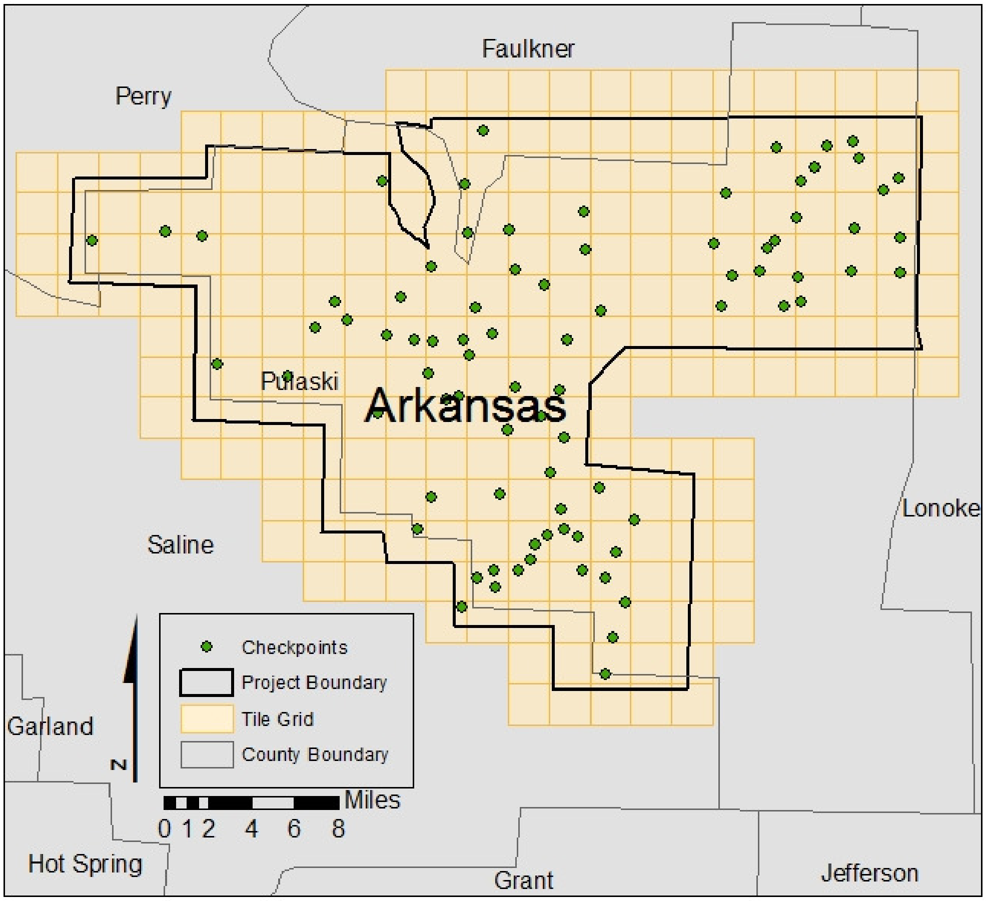


Figure 10– Location of QA/QC Checkpoints

7.4 *Vertical Accuracy Results*

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the LiDAR LAS files.

Land Cover Category	**# of Points**	**FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=0.80 ft**	**CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=1.19 ft**
Consolidated	83		0.28
Open Terrain	21	0.26	

Table 3- FVA and CVA Vertical Accuracy at 95% Confidence Level

The $RMSE_z$ for open terrain tested 0.13 ft, within the target criteria of 0.41 ft. Compared with the 0.80 ft specification, the FVA tested 0.26 ft at the 95% confidence level based on $RMSE_z$ x 1.9600.

Compared with the 1.19 ft specification, CVA for all checkpoints tested 0.28 ft at the 95% confidence level based on the 95th percentile.

Supplemental vertical accuracy (SVA) is tested for each individual land cover category that is not open terrain. SVA uses target values as each land cover category tested does not have to meet the target specification as long as the consolidated vertical accuracy passes. The SVA for all checkpoint categories tested below the target specification of 1.19 ft at the 95% confidence level based on the 95th percentile.

Land Cover Category	**# of Points**	**SVA — Supplemental Vertical Accuracy (95th Percentile) Target=1.19 ft**
Vegetation	22	0.31
Forest	20	0.26
Urban	20	0.27

Table 4- SVA Vertical Accuracy at 95% Confidence Level

The figure below illustrates the magnitude of the differences between the QA/QC checkpoints and LiDAR data. This shows that all LiDAR elevations were within +/- 0.40 ft of the checkpoints elevations.

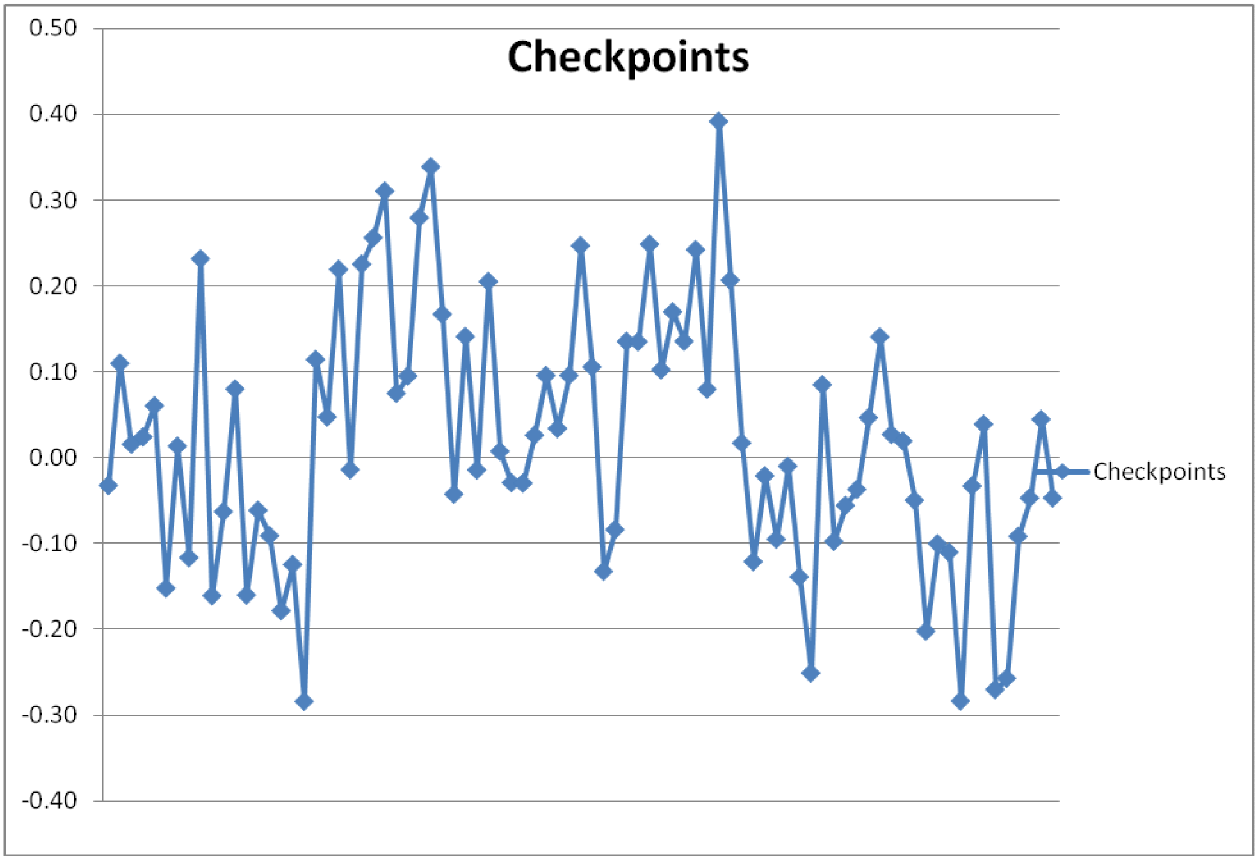


Figure 11 – Magnitude of Elevation Discrepancies

There were no 5% outliers that are larger than the 95th percentile. The table below provides overall descriptive statistics.

100 % of Totals	RMSE (ft) Open Terrain Spec=0.41ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated		0.12	0.02	0.13	0.15	83	-0.28	0.39
Open Terrain	0.13	0.11	-0.03	0.18	0.13	21	-0.28	0.23
Vegetation		0.13	0.10	0.35	0.12	22	-0.04	0.34
Forest		0.14	0.08	0.06	0.16	20	-0.25	0.39
Urban		0.10	-0.05	-0.50	0.11	20	-0.28	0.14

Table 5 — Overall Descriptive Statistics

The figure below illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the LiDAR triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.29 ft and a high of +0.39 ft, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges -0.10 ft to +0.10 ft.

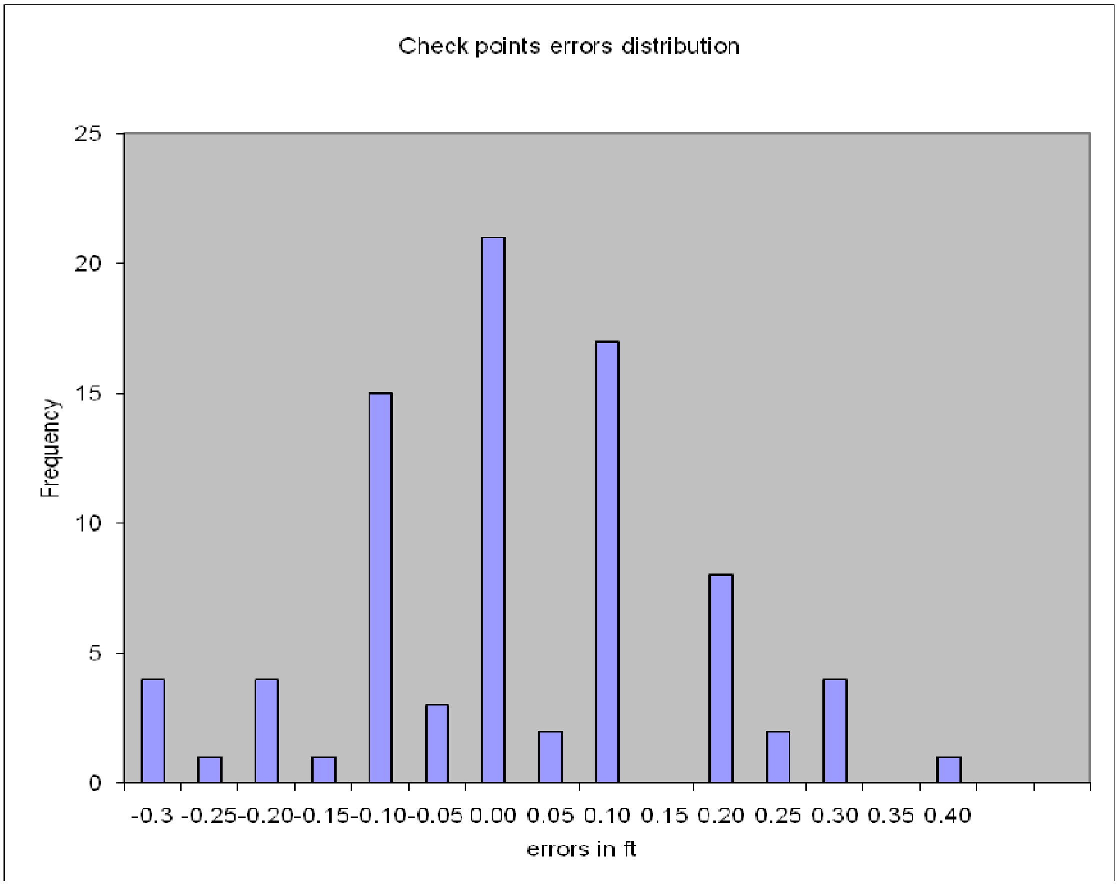


Figure 12 — Histogram of Elevation Discrepancies within errors in feet

8 Breakline Production & Qualitative Assessment Report

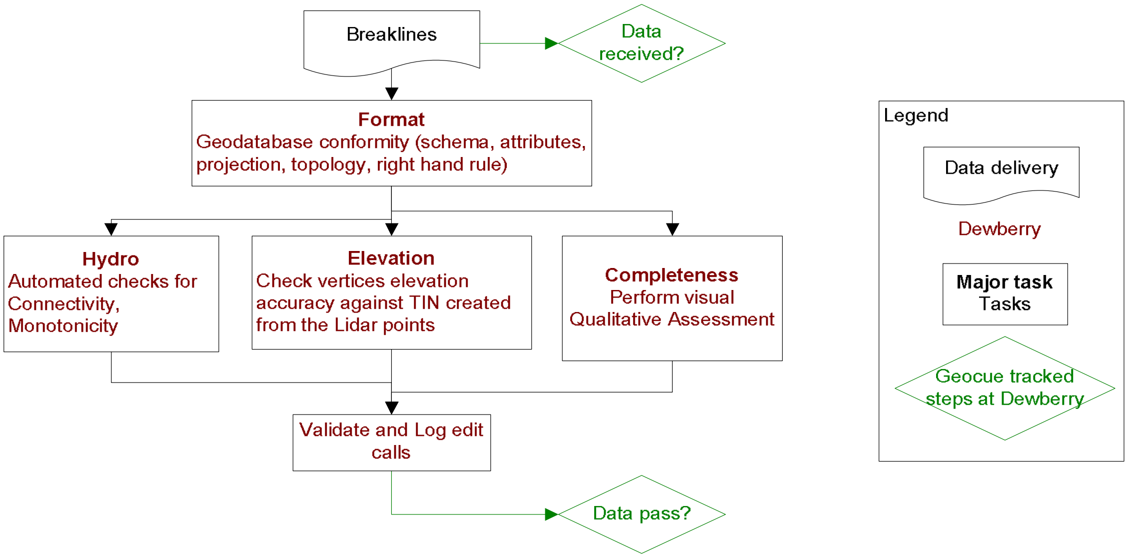
8.1 Breakline Production Methodology

Dewberry used GeoCue software to develop LiDAR stereo models of the USGS PAgis V13 LiDAR Project area so the LiDAR derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using LiDARgrammetry procedures with LiDAR intensity imagery, Dewberry stereo-compiled the two types of hard breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are reviewed in stereo and the lowest elevation is applied to the entire waterbody.

8.2 Breakline Qualitative Assessment

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.



8.3 Breakline Topology Rules

Automated checks are applied on hydro features to validate the 3D connectivity of the feature and the monotonicity of the hydrographic breaklines. Dewberry's major concern was that the hydrographic breaklines have a continuous flow downhill and that breaklines do not undulate. Error points are generated at each vertex not complying with the tested rules and these potential edit calls are then visually validated during the visual evaluation of the data. This step also helped validate that breakline vertices did not have excessive minimum or maximum elevations and that elevations are consistent with adjacent vertex elevations.

The next step is to compare the elevation of the breakline vertices against the elevation extracted from the ESRI Terrain built from the LiDAR ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations do not differ too much from the LiDAR.

Dewberry's final check for the breaklines was to perform a full qualitative analysis. Dewberry compared the breaklines against LiDAR intensity images to ensure breaklines were captured in the required locations. The quality control steps taken by Dewberry are outlined in the QA Checklist below.

8.4 Breakline QA/QC Checklist

Project Number/Description: TO G10PC00013 USGS PAgis V13 LiDAR

Date: 2/29/2012

Overview

☒ All Feature Classes are present in GDB

☒ All features have been loaded into the geodatabase correctly. Ensure feature classes with subtypes are domained correctly.

☒ The breakline topology inside of the geodatabase has been validated. See Data Dictionary for specific rules

☒ Projection/coordinate system of GDB is accurate with project specifications

Perform Completeness check on breaklines using either intensity or ortho imagery

☒ Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency (See Data Dictionary for specific collection rules). NHD data will be used to help evaluate completeness of collected hydrographic features. Features should be collected consistently across tile bounds within a dataset as well as be collected consistently between datasets.

☒ Check to make sure breaklines are compiled to correct tile grid boundary and there is full coverage without overlap

☒ Check to make sure breaklines are correctly edge-matched to adjoining datasets if applicable. Ensure breaklines from one dataset join breaklines from another dataset that are coded the same and all connecting vertices between the two datasets match in X,Y, and Z (elevation). There should be no breaklines abruptly ending at dataset boundaries and no discrepancies of Z-elevation in overlapping vertices between datasets.

Compare Breakline Z elevations to LiDAR elevations

☒ Using a terrain created from LiDAR ground points and water points and GeoFIRM tools, drape breaklines on terrain to compare Z values. Breakline elevations should be at or below the elevations of the immediately surrounding terrain. This should be performed before other breakline checks are completed.

Perform automated data checks using PLTS

The following data checks are performed utilizing ESRI's PLTS extension. These checks allow automated validation of 100% of the data. Error records can either be written to a table for future correction, or browsed for immediate correction. PLTS checks should always be performed on the full dataset.

☒ Perform "adjacent vertex elevation change check" on the Inland Ponds feature class (Elevation Difference Tolerance=.001 feet). This check will return Waterbodies whose vertices are not all identical. This tool is found under "Z Value Checks."

☒ Perform "unnecessary polygon boundaries check" on Inland Ponds and Inland Streams feature classes. This tool is found under "Topology Checks."

☒ Perform "duplicate geometry check" on (inland streams to inland streams), (inland ponds to inland ponds), (inland ponds to inland streams). Attributes do not need to be checked during this tool. This tool is found under "Duplicate Geometry Checks."

☒ Perform "geometry on geometry check" on (inland ponds to inland streams). Spatial relationship is contains, attributes do not need to be checked. This tool is found under "Feature on Feature Checks."

☒ Perform "polygon overlap/gap is sliver check" on (inland streams to inland streams), (inland ponds to inland ponds), (inland ponds to inland streams). Maximum Polygon Area is not required. This tool is found under "Feature on Feature Checks."

Perform Dewberry Proprietary Tool Checks

☒ Perform monotonicity check on inland streams features using "A3_checkMonotonicityStreamLines." This tool looks at line direction as well as elevation. Features in the output shapefile attributed with a "d" are correct monotonically, but were compiled from low elevation to high elevation. These errors can be ignored. Features in the output shapefile attributed with an "m" are not correct monotonically and need elevations to be corrected. Input features for this tool need to be in a geodatabase. Z tolerance is .01 feet. Polygons need to be exported as lines for the monotonicity tool.

☒ Perform connectivity check between (inland ponds to inland streams) using the tool "07_CheckConnectivityForHydro." The input for this tool needs to be in a geodatabase. The output is a shapefile showing the location of overlapping vertices from the polygon features and polyline features that are at different Z-elevation. The unnecessary polygon boundary check must be run and all errors fixed prior to performing connectivity check. If there are exceptions to the polygon boundary rule then that feature class must be checked against itself, i.e. inland streams to inland streams.

Metadata

☒ Each XML file (1 per feature class) is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. Content should be consistent across all feature classes.

Completion Comments: **Complete – Approved**

8.5 Data Dictionary

Dewberry®

LiDARgrammetry Data Dictionary & Stereo Compilation Rules

For the USGS PAgis V13 LiDAR Project

February 23, 2012

8.5.1 Horizontal and Vertical Datum

The horizontal datum shall be North American Datum of 1983, Units in feet. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in feet. Geoid09 shall be used to convert ellipsoidal heights to orthometric heights.

8.5.2 Coordinate System and Projection

All data shall be projected to State Plane Arkansas North, Horizontal Units in feet and Vertical Units in feet.

8.5.3 Inland Streams and Rivers

Feature Dataset: BREAKLINES	**Feature Class:** STREAMS_AND_RIVERS	**Feature Type:** Polygon
Contains M Values: No	**Contains Z Values:** Yes	**Annotation Subclass:** None
XY Resolution: Accept Default Setting	**Z Resolution:** Accept Default Setting	
XY Tolerance: 0.003	**Z Tolerance:** 0.001	

Description

This polygon feature class will depict linear hydrographic features with a width greater than 100 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity and data is required to show "closed polygon". Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small

		branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: Where islands greater than ½ acre in size exist, the feature should be delineated. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

8.5.4 Inland Ponds and Lakes

Feature Dataset: BREAKLINES
Contains M Values: No
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: PONDS_AND_LAKES
Contains Z Values: Yes
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Feature Type: Polygon
Annotation Subclass: None

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

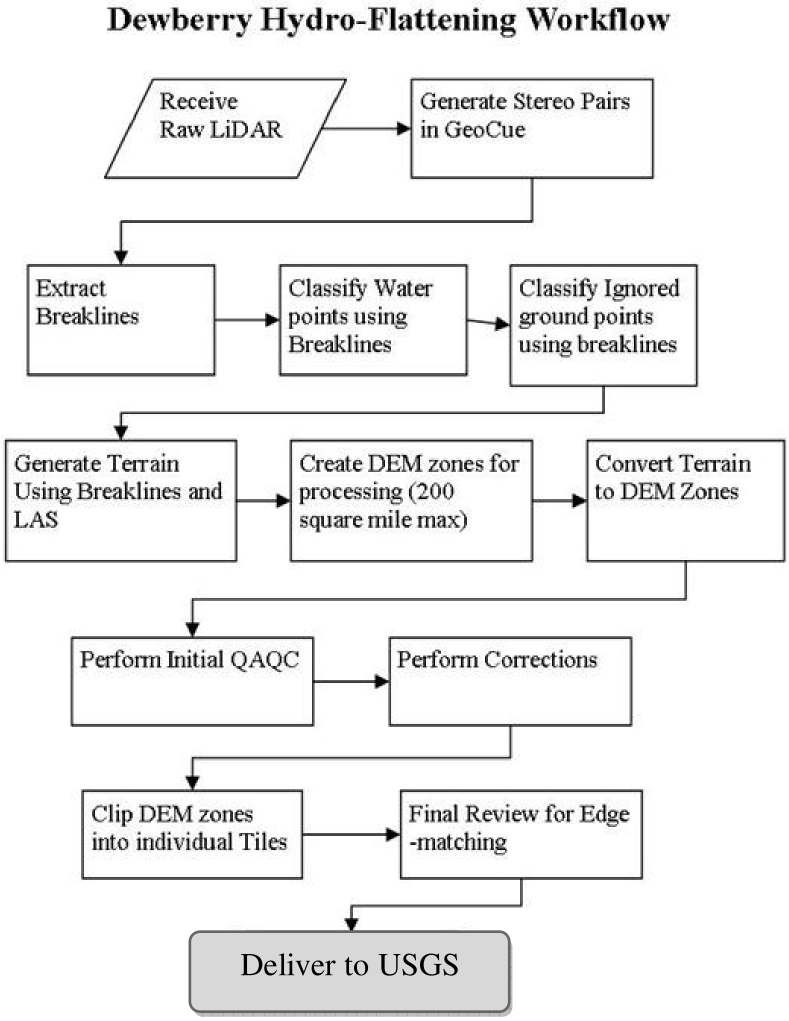
Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. "Donuts" will exist where there are islands within a closed water body feature greater than ½ acre in size.	Water bodies shall be captured as closed polygons with the water feature to the right. <u>The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body.</u> Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. Islands greater than ½ acre in size within the boundary of the water body feature should be delineated so that the island appears as a "hole" in the closed water body feature. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

9 DEM Production & Qualitative Assessment

9.1 DEM Production Methodology

Dewberry's utilizes ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper.



1. <u>Generate LiDAR Stereo Pairs using GeoCue</u>: Create stereo pairs with the raster pixel size being equal to the nominal point spacing. Stereo pairs will be created for Bare-Earth and Full-Point Cloud.
2. <u>Extract Breaklines</u>: Breaklines will be extracted according to the data dictionary outlined on the previous pages.
3. <u>Classify Water Points</u>: LAS point falling within hydrographic breaklines shall be classified to ASPRS class 9 using TerraScan. Breaklines must be prepared correctly prior to performing this task.

4. Classify Ignored Ground Points: Points within a specified distance of breaklines were removed from the ground classification and re-classified to class 10.
5. Terrain Processing: A Terrain will be generated using the Breaklines and LAS data that has been imported into Arc as a Multipoint File. If the final DEMs are to be clipped to a project boundary that boundary will be used during the generation of the Terrain.
6. Create DEM Zones for Processing: Create DEM Zones that are buffered by 2 tiles around the edges. Zones should be created in a logical manner to minimize the number of zones without creating zones to large for processing. Dewberry will make zones no larger than 200 square miles (taking into account that a DEM will fill in the entire extent not just where LiDAR is present). Once the first zone is created it must be verified against the tile grid to ensure that the cells line up perfectly with the tile grid edge.
7. Convert Terrain to Raster: Convert Terrain to raster using the DEM Zones created in step 6. In the environmental properties set the extents of the raster to the buffered Zone. For each subsequent zone, the first DEM will be utilized as the snap raster to ensure that zones consistently snap to one another.
8. Perform Initial QAQC on Zones: During the initial QA process anomalies will be identified and corrective polygons will be created.
9. Correct Issues on Zones: Corrections on zones will be performed following Dewberry's in-house correction process.
10. Extract Individual Tiles: Individual Tiles will be extracted from the zones utilizing a Dewberry proprietary tool.
11. Final QA: Final QA will be performed on the dataset to ensure that tile boundaries are seamless.

9.2 DEM Qualitative Assessment

Dewberry performed a comprehensive qualitative assessment of the DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. Dewberry uses Global Mapper to perform this review. Corrections are applied in Arc Map. Dewberry creates HillShade models and overlays a partially transparent colorized elevation model in order to perform the corrections. The last step is to load the DEM data into Global Mapper to ensure that the corrections are acceptable, all files are readable, and that no artifacts exist between tiles. The figure below, illustrates the detail of the final DEMs and how the DEMs display elevations that are just below the elevations of the immediately surrounding terrain within hydrographic features.

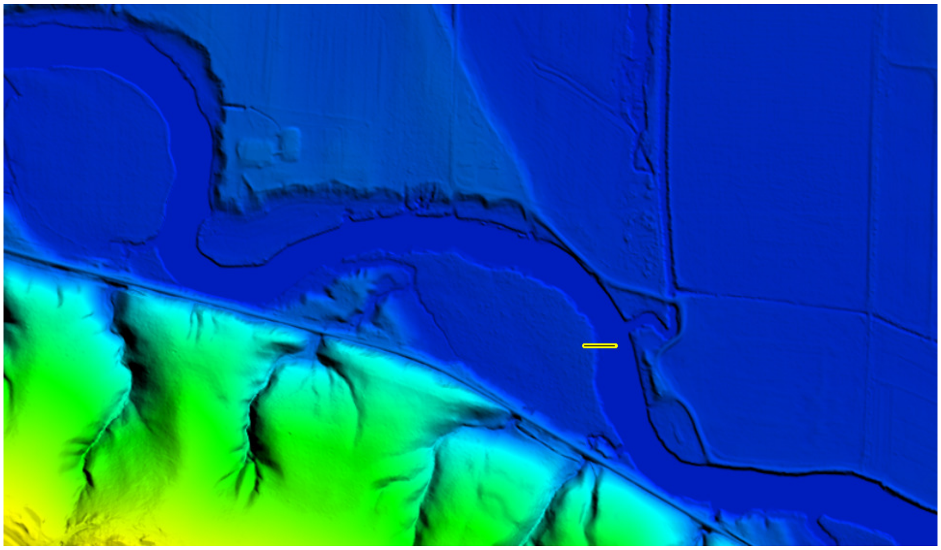
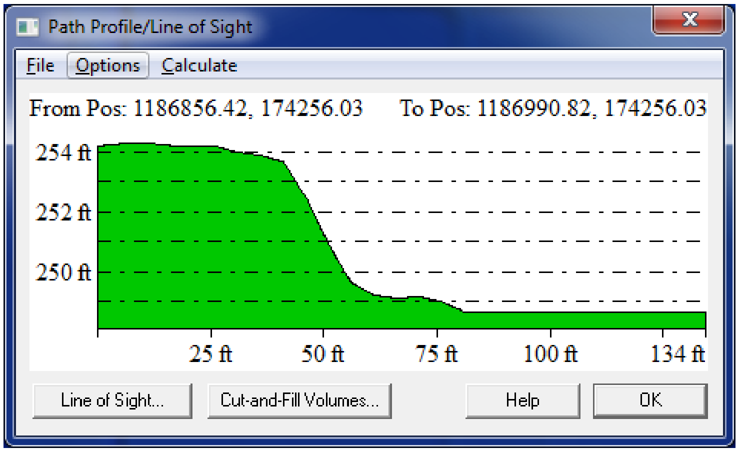


Figure 13- DEM for tile 16SCF007170



From Pos: 1186856.42, 174256.03 To Pos: 1186990.82, 174256.03

Figure 14- Tile 15WU1817. Profile showing the elevation within the hydrologic features are below the surrounding terrain.

9.3 DEM QA/QC Checklist

Project Number/Description: TO G10PC00013 USGS PAgis V13 LiDAR
Date: 2/29/2012

Overview

☒ Correct number of files is delivered and all files are in ESRI Grid format
☒ Verify Raster Extents
☒ Verify Projection/Coordinate System

Review

☒ Manually review bare-earth DEMs with a hillshade to check for issues with hydro-enforcement process or any general anomalies that may be present. Specifically, water should be flowing downhill, water features should NOT be floating above surrounding terrain and bridges/box culverts should NOT be present in bare-earth DEM. Hydrologic breaklines should be overlaid during review of DEMs.

- ☒ Overlap points (in the event they are supplied to fill in gaps between adjacent flightlines) are not to be used to create the bare-earth DEMs
- ☒ DEM cell size is 5 feet
- ☒ Perform final overview in Global Mapper to ensure seamless product.

Metadata

- ☒ Project level DEM metadata XML file is error free as determined by the USGS MP tool

- ☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc.

Completion Comments: **Complete - Approved**